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Low-Profile Fluorescent Uplight Product Feasibility Analysis

Technical Note

October 6, 1999

Introduction

One of the most common forms of commercial indoor lighting is indirect fluorescent. Indirect fluorescent lighting provides a "soft" lighting effect with virtually no glare. Installed frequently in atriums or other large open spaces, the use of indirect fluorescent lighting in offices is limited due to their lower ceilings and the present lighting fixture's high setback requirements. For example, building codes typically limit suspended objects to a minimum of 7' 6" above the floor. If the height of the office ceiling is 8.5', a fixture can only be suspended 1 foot, measured to the bottom of the fixture. While it is possible to install current fixtures at this setback, the light throw will be extremely limited. In order to achieve desired uniformity levels, designers would have to install a large number of fixtures on very small centers, making the installation cost prohibitive. The likelihood of unsightly striations would be high and difficult to control.

Advanced Optical Technologies has completed a product concept feasibility analysis to determine the potential performance capabilities of a Constructive Occlusion-based Low-Profile Fluorescent Uplight (LPFU) Product design. The objective of the product feasibility analysis was to develop a LPFU design that would offer the following:

- employs one linear fluorescent lamp (variable wattage & length)
- is suspended a maximum of 9" from the ceiling (measured to the top of the fixture)
- achieves distribution max-to-min uniformity of better than 4:1 on 10' centers
- provides comparable work plane illuminance to current products

Conceptual Design

AOT began the feasibility assessment by developing a conceptual design for a Constructive Occlusion-based LPFU lighting product. (It should be noted that the design has not yet been optimized for performance, nor have specific mechanical design features been incorporated.)

The Constructive Occlusion-based LPFU conceptual design satisfies the major objectives of the feasibility analysis, achieving uniformity of 4:1 on 10' centers -- **while limiting the suspension of the uplight fixture to 9"**. This represents an important breakthrough. While other manufacturers offer products that have 4:1 uniformity on 10' centers, they can only do so providing their setback is increased to 15" - 18". In doing so, the fixtures extend below the building code limits, thus eliminating these fixtures from consideration for installation in offices with 8.5' ceilings. While it is physically possible to install these fixtures at lesser suspension heights, doing so results in extremely poor uniformity, well above the IES ceiling illumination uniformity recommendation of 4:1.

To achieve the desired uniformity of 4:1 on 10' centers using a luminaire suspension of 9", AOT added a design feature, termed the "fan", to the Constructive Occlusion "Mask and Cavity" system that increases light throw to the sides. This combination enables us to minimize fixture setback, without sacrificing uniformity or light throw. Figure 1 shows a cross-section of the LPFU conceptual design that incorporates the "mask and cavity" and "fan" design features.

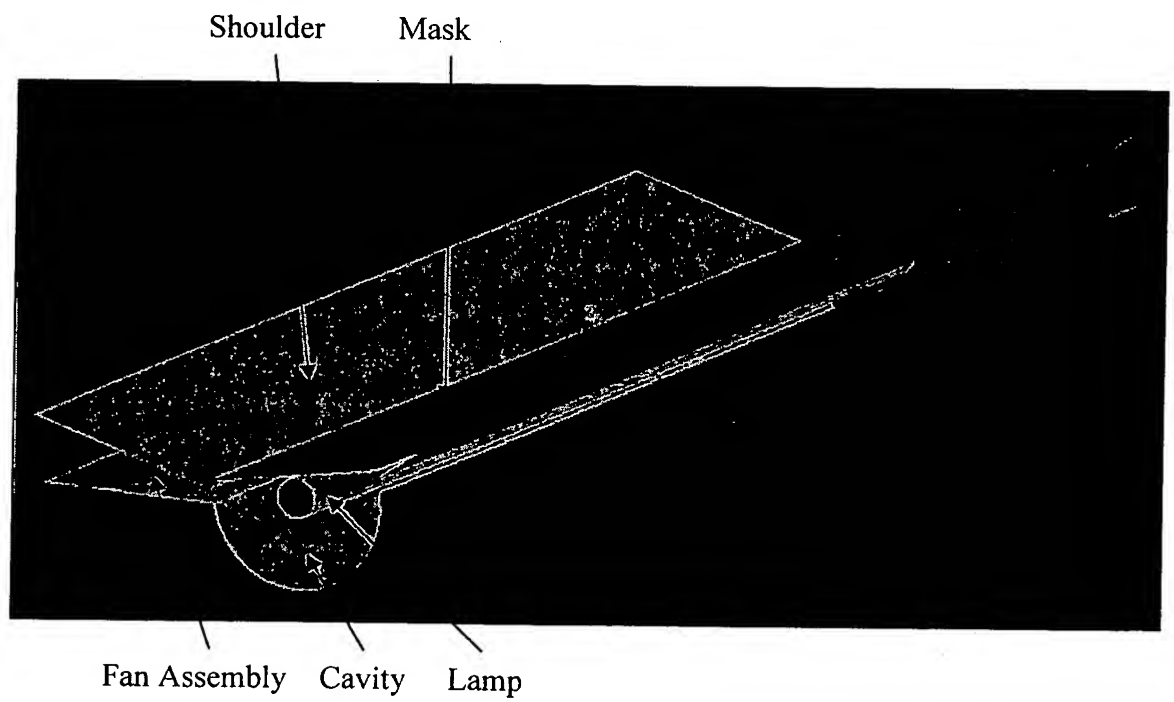

Figure 1. Cross-Section of Lamp Assembly Array

The design consists of a semi-cylindrical cavity with a radius of 1.5 inches. The length of the cavity is dependent upon the lamp length. The mask is positioned over and centered along the longitudinal axis of the cavity at a height 0.375 inches above the cavity. The mask's width is 2.94 inches. The central axis of the lamp is positioned along the cavity's central axis, 0.5 inches below the mask. The lower half of the "fan assembly" extends outward from the cavity opening for 3.0 inches at an angle 10° above horizontal for the entire length of the cavity. The upper half of the fan assembly is positioned such that the interior edge bisects the opening between the mask and cavity, extending outward 3.0 inches at an

angle 25° above the horizontal. The upper half of the fan assembly serves two functions, 1) the interior surface is the upper half of the optical fan and 2), the exterior surface serves as the "mask and cavity's" shoulder.

To further assist in understanding this design, Figure 2 depicts an artist's rendering of the conceptual design (mounting rods removed to show detail).

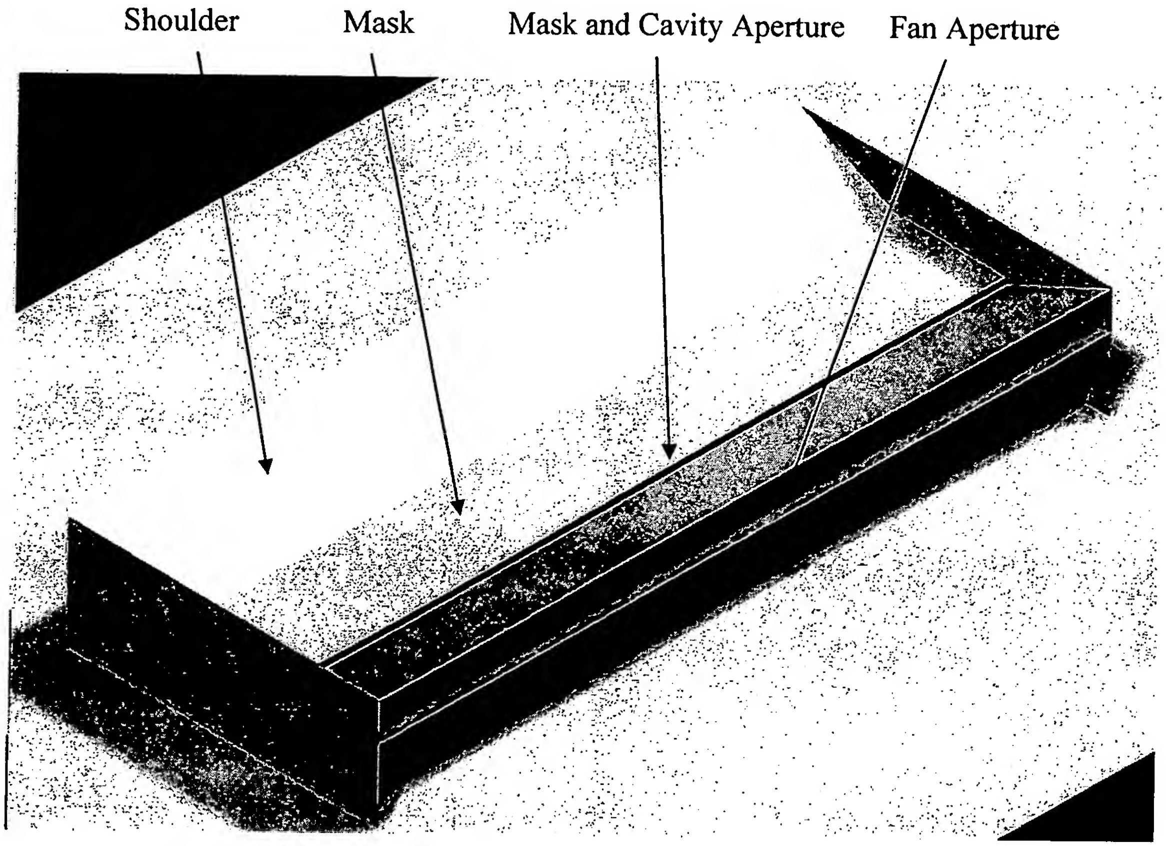

Figure 2. Artist's Rendering of Constructive Occlusion-Based, Suspended Fluorescent Uplight Fixture
(Mounting rods omitted to show detail)

The concept of operation of the light fixture is that a portion of the light generated by the lamp is directed into the fan assembly which "throws" the light to the extreme angles of the fixture's field of view. The remainder of the light is reflected within the "cavity and mask" structure, escaping through an aperture and filling in the remainder of the field of view. It is this combination of the "mask and cavity" and "fan" that enables us to generate the light distribution that satisfies the performance objectives. The mask and cavity is coated with a highly reflective (>95%) lambertian material (e.g., Gore WhiteStar™ or Dupont's Tyvek™) over a stamped substrate. The optical surfaces of the fan assembly and shoulder are specular (e.g., Alanod Miro 5).

Photometric Analysis

The real measure of the fixture's performance is how well it illuminates the area of interest. As IES classifies the fixture as an "indirect" luminaire we must consider two measures of merit, ceiling and workplane illuminance. To replicate an office environment, individual fixtures were assembled into a typical office installation. In this instance, five rows of single-lamped fixtures, suspended 9" on 10' centers, were modeled within a 56' x 56' office. The ceiling height was 8.5'. The reflectivity of the ceiling was assumed to be 80%, wall reflectivity was 50%, and floor reflectivity was 20%. To determine predicted ceiling and workplane illuminance, AOT first modeled the conceptual design using Photopia to determine the conceptual design's photometric distribution and light output. The Photopia report of the fixture's output performance is included as Appendix A. The next step was to use Lumen Micro 7 to determine ceiling and workplane illuminance levels.

Figure 3 and Table 1 illustrates the conceptual design's ceiling illuminance. As shown in the figure and table, ceiling uniformity is very good with a max:min uniformity ratio of 2.9:1. This is well within the IES recommendation of 4:1. In addition, maximum ceiling luminance was calculated to be 163 cd/m^2, again well within the IES recommendation that maximum ceiling luminance not exceed 850 cd/m^2 when video display terminals are in operation.

Figure 4 and Table 2 depicts the conceptual design's workplane illuminance. As expected, workplane uniformity is excellent with a max:min uniformity ratio of 1.1:1. The average foot-candle level on the workplane was projected to be 27.1 fc. It is expected that this illumination level will rise significantly after the conceptual design is optimized for performance. For example, the optical efficiency of the conceptual design is projected to be 56%, comparable to previous conceptual design levels. Historically, we would expect the optimized efficiency to reach the 70-75% range. This should result in illuminance levels on the order of 35 fc, given the conceptual design configuration remains the same. Higher foot-candle illumination levels are possible simply by increasing lamp wattage or by adding additional lamps

Conclusion

Our assessment is that a low-profile fluorescent uplight product based upon a Constructive Occlusion-based design is technically feasible. Additional design analysis is necessary to optimize the conceptual design for efficiency and to obtain further improvements to the light distribution. We do not expect the Constructive Occlusion components to add significantly to the fixture's cost (Historically, the use of Constructive Occlusion is cost neutral.).

The critical optical engineering requirement that led to AOT's development of Constructive Occlusion was the need to provide tailored light distribution with increased uniformity over much wider fields of view than state-of-the-art fixtures could economically provide. A low-profile fluorescent uplight product is an attractive candidate to demonstrate the ability of a Constructive Occlusion-based design to achieve a desired light distribution objective.

This technical note was prepared by Jack C. Rains, Jr., General Manager of Advanced Optical Technologies, LLC. This document is confidential and contains proprietary information of Advanced Optical Technologies, LLC.